52. IWK

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FACULTY OF COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME II

Session 6 - Environmental Systems: Management and Optimisation

Session 7 - New Methods and Technologies for Medicine and Biology

Session 8 - Embedded System Design and Application

Session 9 - Image Processing, Image Analysis and Computer Vision

Session 10 - Mobile Communications

Session 11 - Education in Computer Science and Automation

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff	Professor Christoph Ament
Rector, TU Ilmenau	Head of Organisation

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Thomas Rauschenbach / Torsten Pfützenreuter / Zhang Tong

Model based water allocation decision support system for Beijing

INTRODUCTION

Beijing is a fast growing city. For several years the total population has increased steadily as well as the economy has grown very fast. The trend will continue in the future. An increasing demand of several resources, especially water, follows from this development. In connection with the semi-arid climate, these are the causes for the scarcity of the resource water in Beijing. Without consideration of sustainable resources use, the very positive development of the region is endangered.

Central management of all usable water resources for the city is urgently needed. That is why the Beijing Water Authority (BWA) is developing a "Capital Water Resources Allocation Decision Supporting System" to assist in the management of all the water resources of the capital of the People's Republic of China.

The general objectives of the joint Chinese - German project "Toward Water-Scarcity Megalopolis's Sustainable Water Management System" are as follows:

- To build rainfall - runoff models for the catchment areas of the most important reservoirs in the Beijing region with the aim to improve precision of runoff forecast.
- To establish water demand prediction models for a large city to solve the problem of water demand prediction under different circumstances.
- To built the joint operation model of multi water resources including surface water, groundwater, recycled water and water diversion as well as to primarily solve the allocation problem of Beijing water resources.
- To primarily establish operation-orientated Beijing water resources integrated allocation decision supporting system (DSS) and provide techniques for water resources management and decision-making.

The project is under the charge of BWA, German Fraunhofer Institute for Information and Data Processing and Fraunhofer Center for Applied Systems Technology. The project will be completed until 2008.

The DSS will realize an optimal allocation of existing water resources such as surface water, ground water, recycled water and transferred water. That means an multiple optimization problem has to be solved [5]. Therefore, a goal function and a simulation model of the water resources as well as of the water supply system are necessary. In the first phase of the project the simulation model of the Beijing water supply system will be developed. Starting point for this development is a rough model for the simulation of the surface and groundwater resources. This model meets the demands for a decision support system with respect to accuracy and simulation speed [6]. The model takes account of

- the Miyun, Guanting, Huairou and Baihebao reservoirs and their catchment areas,
- the groundwater storage,
- the rivers and channels linking the reservoirs to the city and
- the pattern of consumption in households, industry andagriculture.

This paper presents the simulation model and the first experiences with this model as well as a first definition for a goal function for use in the DSS.

The authors thank the German Ministry of Education and Research (BMBF) and the Chinese Ministry of Science and Technology (MOST) for funding this project.

STRUCTURE OF DECISION SUPPORT SYSTEM

The objective of the project is to establish an integrated intelligent water resources allocation decision support system based on GIS. It uses advanced computer and net work technology and it implements a man-machine-interface between decision makers and the system. Fig. 1 shows the logical structure of the DSS which will be developed.

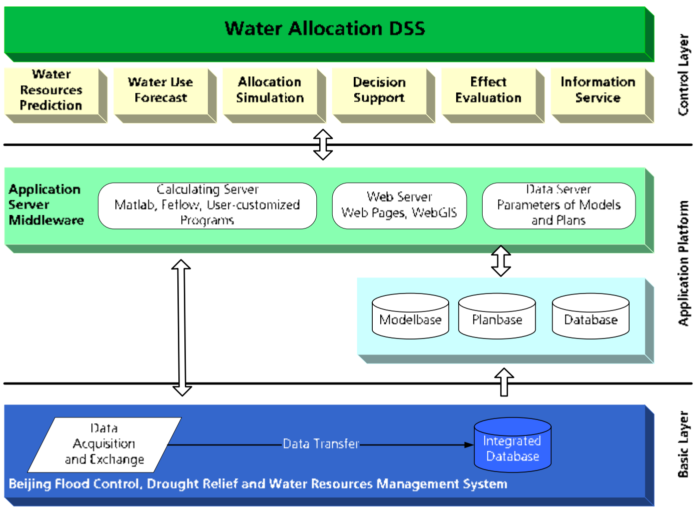

Fig. 1 The logical structure of the "Capital Water Resources Allocation Decision Supporting System"

The DSS is designed as a distributed system, which consists of three layers. These are the basic layer, the application layer (application platform) and the control layer. In the basic layer, the functions for data management and data storage are concentrated. The simulation models and the optimization strategies for decision-making are located in the application layer. Man-machine-interface is provided by the control layer. From here, the locally distributed users can access data and simulation results as well as optimization results. Therefore different rights of access can be assigned to the users.

STRUCTURE OF THE WATER SUPPLY SYSTEM

The structure of the system is shown in Fig. 2. All essential parts of the Beijing water supply system will be considered in the model [1]. There are the four reservoirs Miyun, Huairou, Baihebao and Guanting. The catchments area models are integrated in this system in order to take into account the precipitation and the evapotranspiration. Further sources are groundwater storages. Furthermore there are the water transportation systems, the waterworks and the customers.

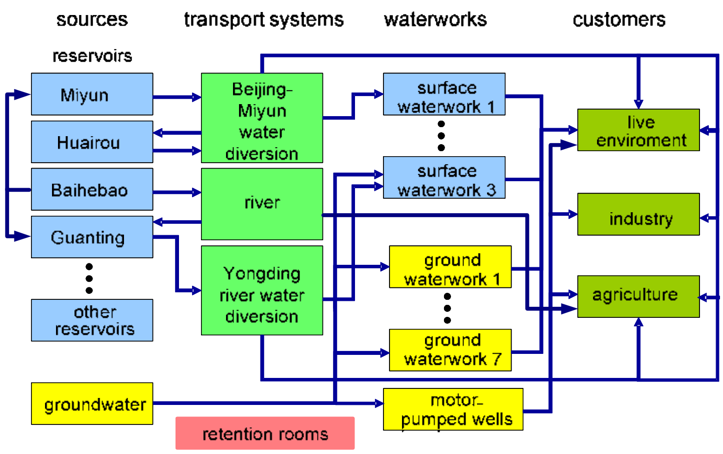

Fig. 2 Structure of the Beijing water supply system

SAMPLE SIMULATION

To prove that the simulation model works, a rough approximation of the Beijing situation was taken as a sample for simulation. The Library “ILM-RIVER” is used for simulation [3]. Fig. 3 shows time series of precipitation and evapotranspiration for the year at hourly intervals. The sum of precipitation for the year is 578 mm.

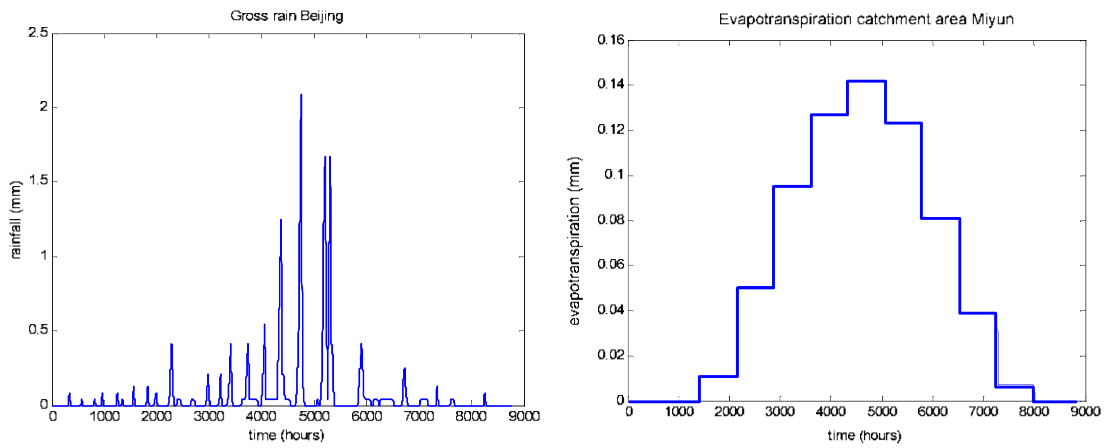

Fig. 3 Assumed annual rainfall and evapotranspiration for the Beijing area

Some simulation results shall be shown now. The water flowing from the Beijing catchment area in the form of groundwater flow as well as the water level in the groundwater storage are represented in Fig. 4. The maximum of the catchment output is postponed by approximately 1000 hours from the time of maximum precipitation and considerably smoothed. At the beginning of the year the water level is still 20 m. At the end it is 19.38 m and so has dropped by 62 cm a year. Changes to the water table are positive under the influence of additions from the catchment area and from channels and the river network, and negative under the influence of outflow to waterworks and pumping stations.

Fig. 5 shows the water inflow into the Miyun reservoir and the appropriate water level. The peaks of the inflow can get up to practically 1000 m³/s. The inflow from the groundwater is characterised by a large delay-time and dead-time. The figure taken for the beginning of the year was 24 m, the maximum level. At the end of the year the reservoir does still have a level of 22.5 m. The downward slope in the graph between 0 and 4300 hours is to be attributed to the effect of evaporation, of water diversion into the Beijing-Miyun channel at 50 m³/s, and into the river Chaobai at 30 m³/s, and of the demand from the No. 9 waterworks at approx. 10 m³/s. The little additional groundwater coming from the catchment areas fails to compensate for these outflows. The start of the rainy season becomes apparent at 4300 hours. The inflows are then greater than the outflows. The water level rises until about at the 7000th hour. After that, the outflow again dominates and the level at the end of the year is 22.5 m. If the outflow regime selected is continued, a similar inflow figure over 5 years would mean that considerable restrictions must be set on consumption.

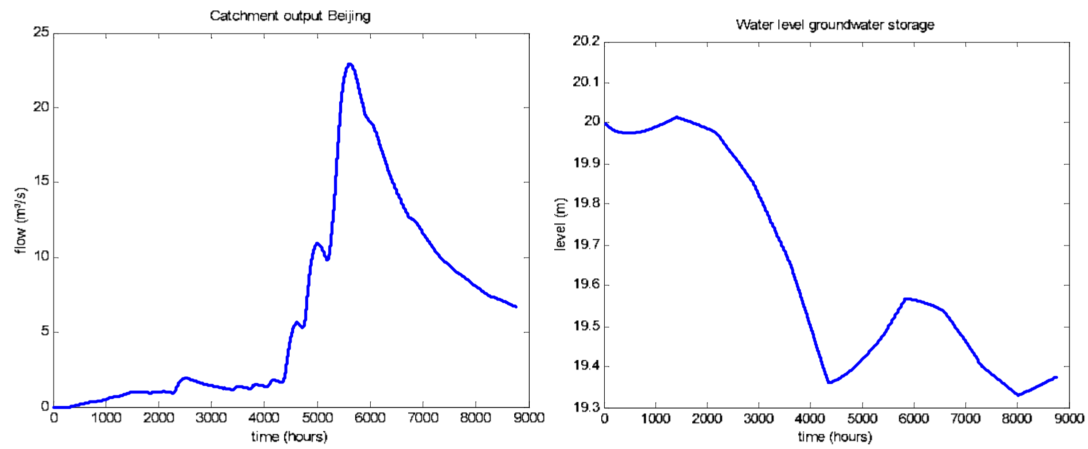

Fig. 4 Inflow of the city catchment area into the groundwater storage of the city region and the water level of this groundwater storage

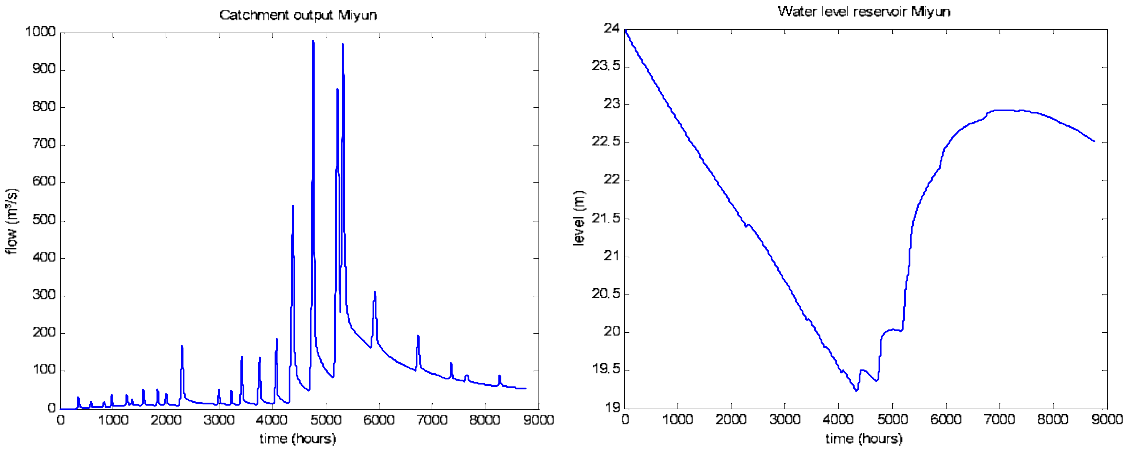

Fig. 5 Runoff from the catchment to Miyun reservoir and water level in the Miyun reservoir

GOAL FUNCTION FOR OPTIMIZATION

The essential aims of the project are to prevent the water resources (especially groundwater) from decreasing and to guarantee the water supply of households, industry and agriculture. In order to achieve these goals a multiple criteria optimization problem has to be solved [2], [4], [7]. A first approach for a goal function I(t) to be minimized is defined as follows:

$$I(t) = \alpha_1 \cdot I_1(t) + \alpha_2 \cdot I_2(t) + \alpha_3 \cdot I_3(t) + \alpha_4 \cdot I_4(t) \quad \text{with} \quad \sum_{i=1}^{4} \alpha_i = 1. \tag{1}$$

In eq. (1) the sub criteria $I_i(t)$ have the following meaning:

1. The groundwater level change $\Delta H_G(t)$:

$$I_1(t) = \begin{cases} \min\left(-\Delta H_G(t)\right) & \text{for} \quad 5 \text{ to } 9 \text{ years} \left(\Delta H_G(t) \le 0\right) \\ \Delta H_G(t) & \text{for} \quad 10 \text{ to } 14 \text{ years} \left(\Delta H_G(t) \approx 0\right) \\ \max\left(\Delta H_G(t)\right) & \text{for} \quad \ge 15 \text{ years} \left(\Delta H_G(t) > 0\right) \end{cases}$$

2. The supply deficits of households $D_H(t)$, industry $D_I(t)$ and agriculture $D_A(t)$ in the following two possible forms:

a. Mean deficit:

$$I_{2,3,4}(t) = D_{H,I,A}(t) = \frac{1}{n}\sum_{i=1}^{n}(d_i - s_i)^+$$

$$\text{with } (X)^+ = \begin{cases} X & \text{for} \quad X > 0 \\ 0 & \text{for} \quad X \leq 0 \end{cases}$$

with d_i demand per time unit and s_i supply per time unit.

b. Days or months with deficit:

$$I_{2,3,4}(t) = D_{H,I,A}(t) = \sum_{j=1}^{n} g^j$$

$$\text{with } g^j = \begin{cases} 1 & \text{for} \quad s_i < d_i \\ 0 & \text{otherwise.} \end{cases}$$

In the next phase of the project, this goal function will be used for the optimization of water resources allocation in Beijing. That means the DSS delivers optimal trajectories (in the sense of the goal function) for the control of reservoirs, sluices pumping stations etc. An essential precondition for this way of proceeding is the simulation model above described.

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